

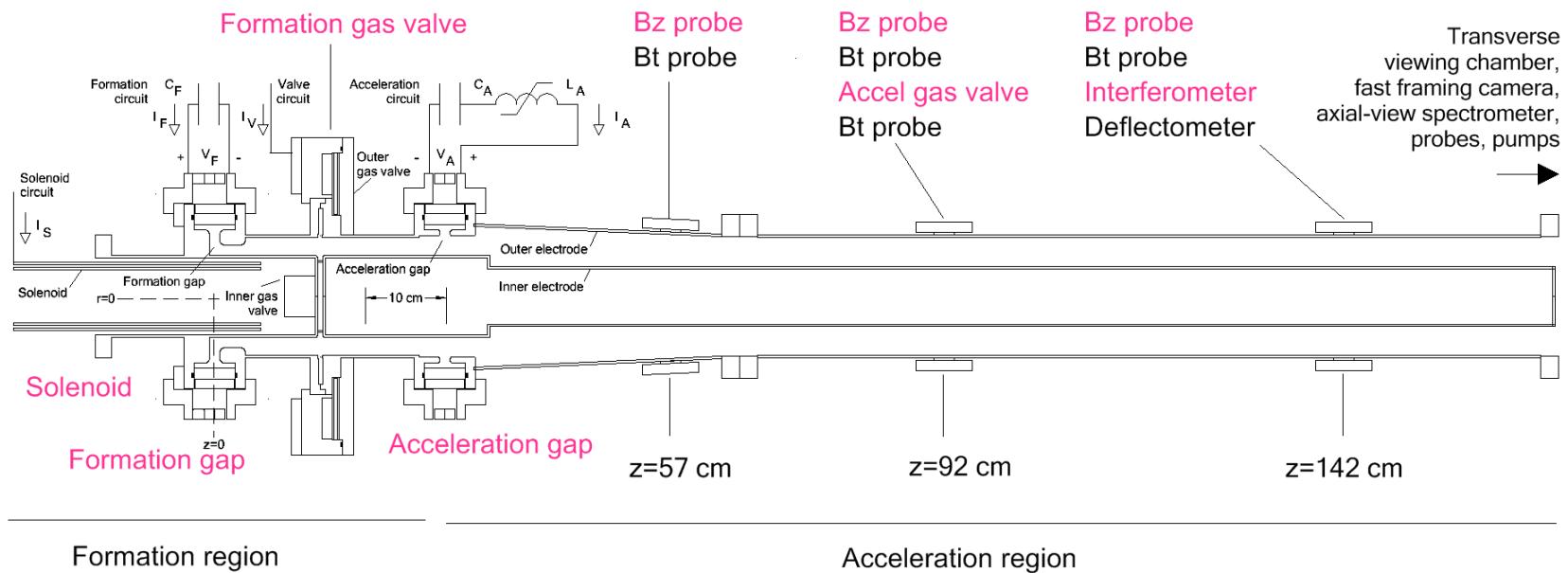
Innovative Diagnostics Development for Magnetic Inertial Fusion

David Q. Hwang, R. D. Horton, R. W. Evans
collaboration with

D. Buchenauer, R. Klauser, J. Johnson, G. Umont,
N. C. Luhmann, MMWG group

*Dept. of Applied Science/ CALFUSE Center, UC Davis, UC
Davis/Livermore, Livermore CA USA 94550*

CTIX experimental geometry



CTIX Plasma Jet Parameters

Switch-less spheromak accelerator

Working Parameters

Rep-rate: .5 Hz

n_e : up to $5 \cdot 10^{15} \text{ cm}^{-3}$ (acc. Puffing)

T_e : < 10 eV

Mod(B): 0 to 1 T

V_{CT} : up to 300 km/sec

D_{CT} : ~15 cm [diameter]

L_{CT} : ~30 cm [length]

Goal Parameters

up to 10 Hz

$1 \cdot 10^{17} \text{ cm}^{-3}$ (compression/stagnation)

<< 10 eV

0 CT-field with high Z inj.

100 to 150 km/sec at
high CT mass

< 5 cm (compressed)

< 10 cm (compressed)

Density Build-up

:

No gas puff

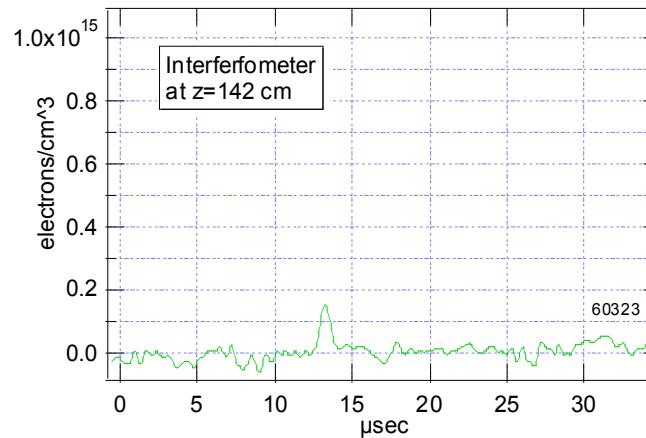
7/9 kV formation/accel

 $1.5 \times 10^{14} \text{ cm}^{-3}$ peak

212 km/sec

25 J kinetic energy

2.0% efficiency



Gas puff

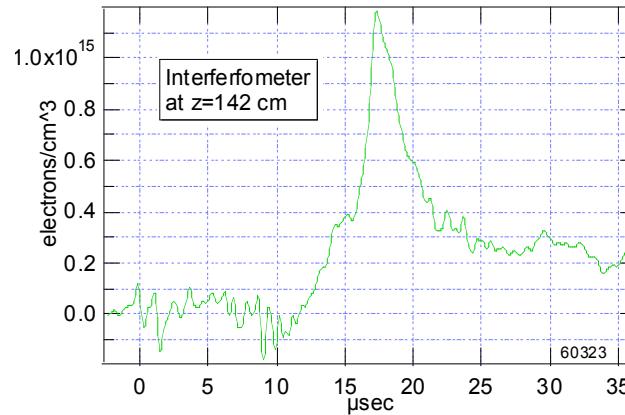
11/13 kV form/accel

 $1.2 \times 10^{15} \text{ cm}^{-3}$ peak

128 km/sec

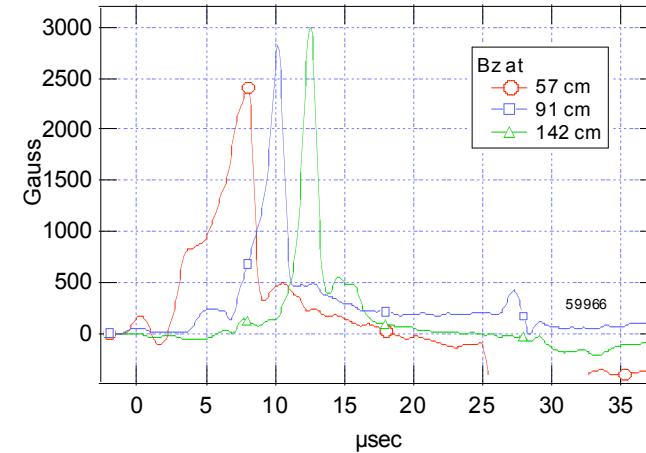
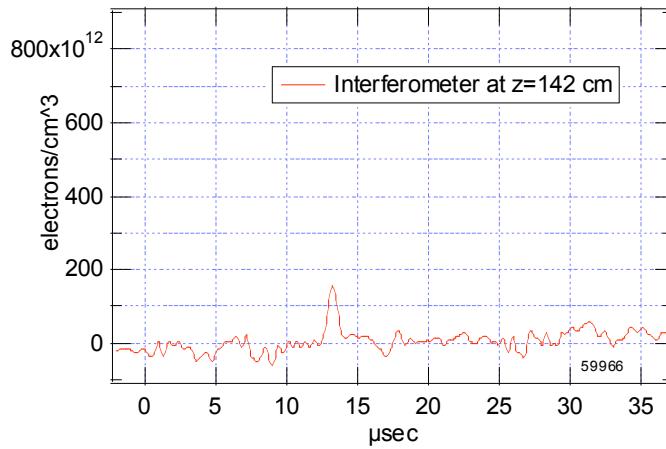
260 J kinetic energy

22% efficiency

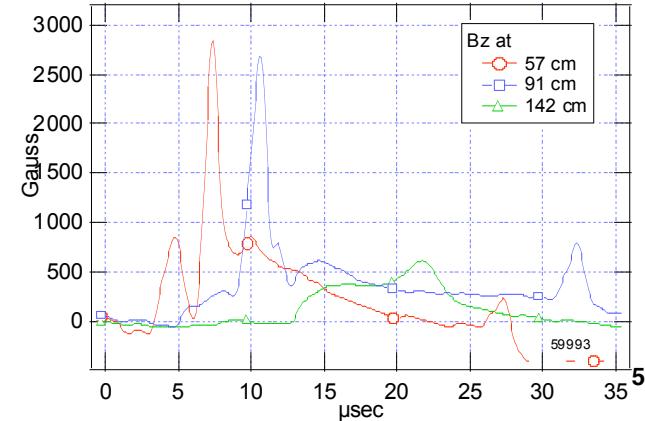
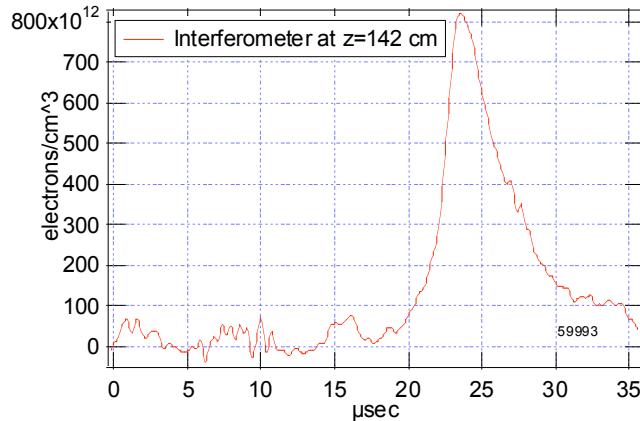


Larger accelerator-region gas puffs can increase plasma density while reducing internal magnetic field

No
gas
puff



With
gas
puff



Methods to introduce high-Z materials in acceleration region for B-field reduction

- **High-Z gas puffing**

- Molecular (N₂, SF₆, WF_{6,,})
- Noble (Ar, Ne, Xe)
- Organometallic

- **High-density pulse evaporation injection**

- High pulsed current wire evaporation in acceleration region
- Insulator coated wire heating
- Al, Fe, Ti, W

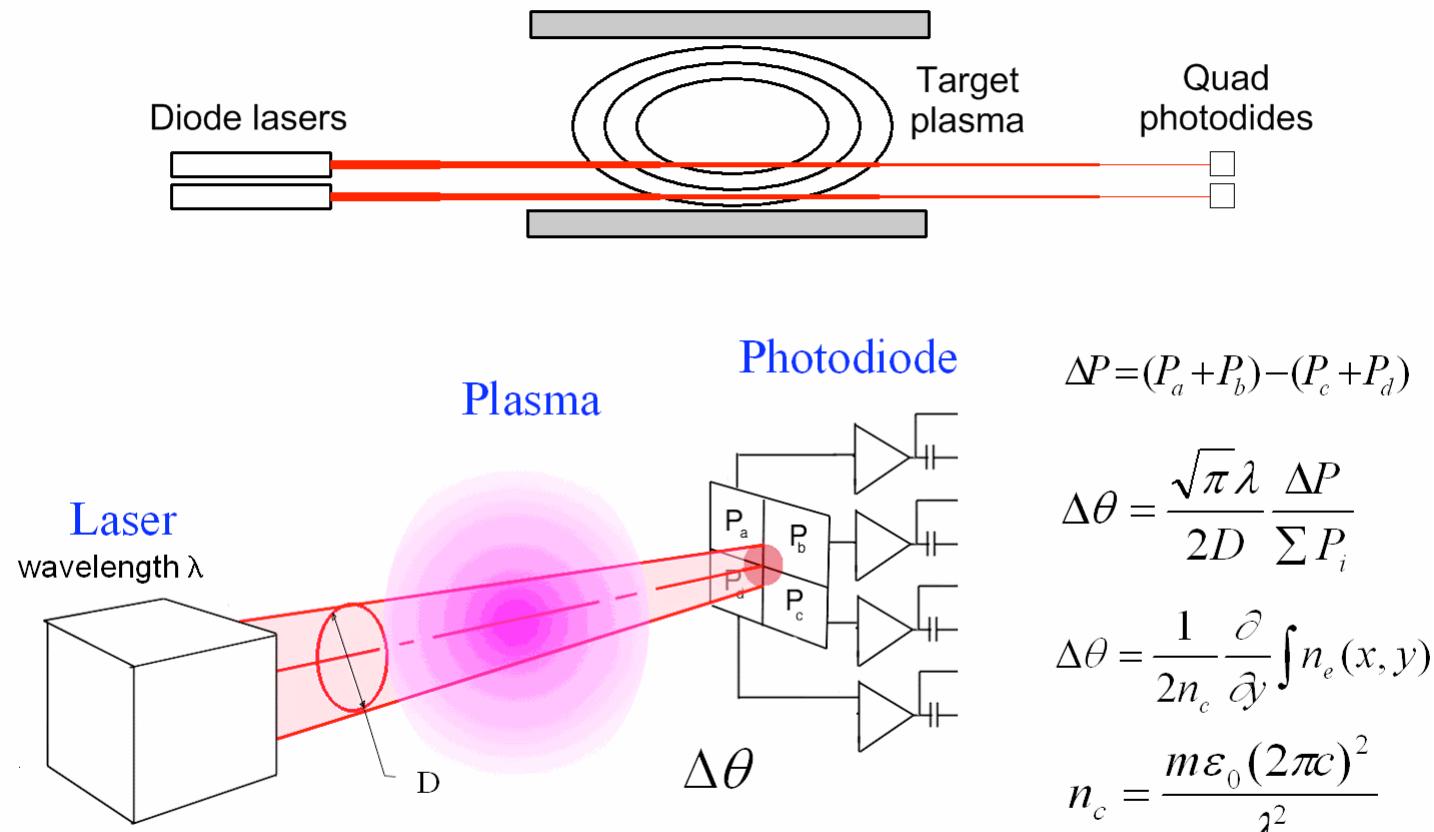
- **Laser Blow-Off in-line with CT**

- High Z, High density
- Control Vapor density profile with shaped target

Diagnostic development for plasma jet and MIF target

- **Deflectometry measurement of line-averaged plasma density gradient for target compression dynamics/plasma jet**
 - Multiple detector array for un-magnetized plasma jets
 - Detection of high gradient phenomena such as shocks during merging jets
 - Short wavelength laser for compression/jet measurement
 - Advantage over interferometry in short wavelength regime
- **THz electron cyclotron emission for target field compression**
 - THz Sources and mixer developed through other programs
 - MIF target compression favors cyclotron emission study
- **THz reflectometry for target density compression/plasma jet speed**
 - Probe density compression and target length evolution
 - Terminal unmagnetized jet speed

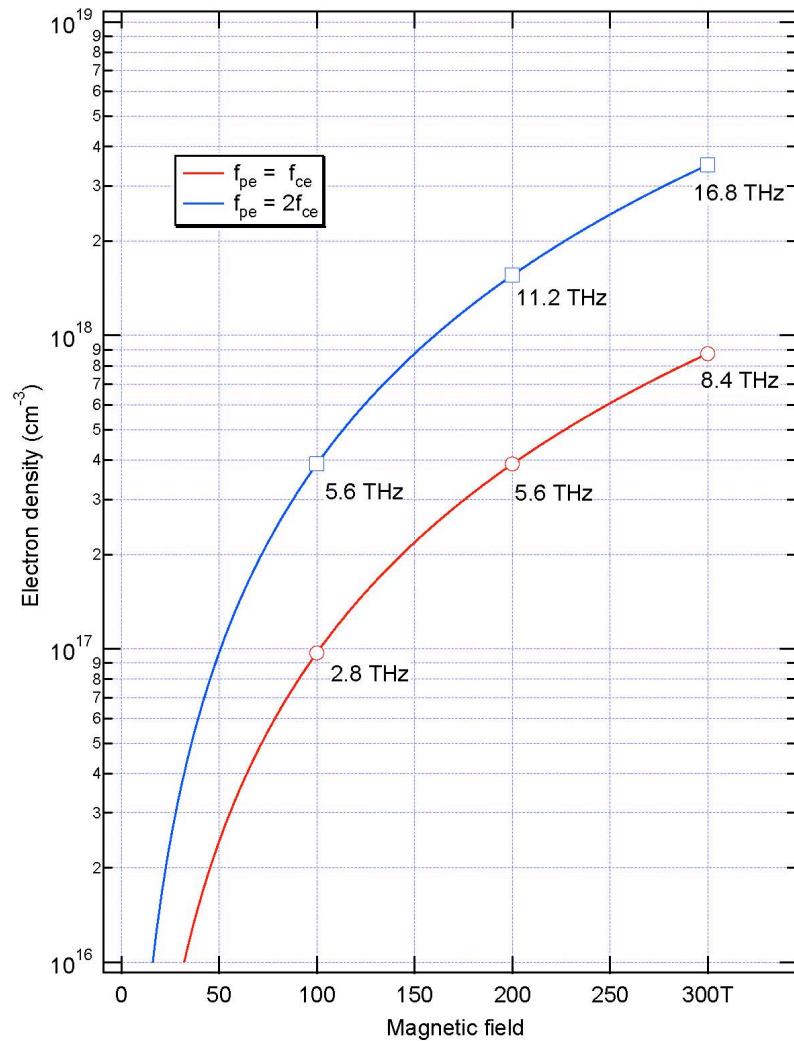
Laser deflection diagnostic (in use on CTIX)



Deflectometry Blue/UV Laser Sources

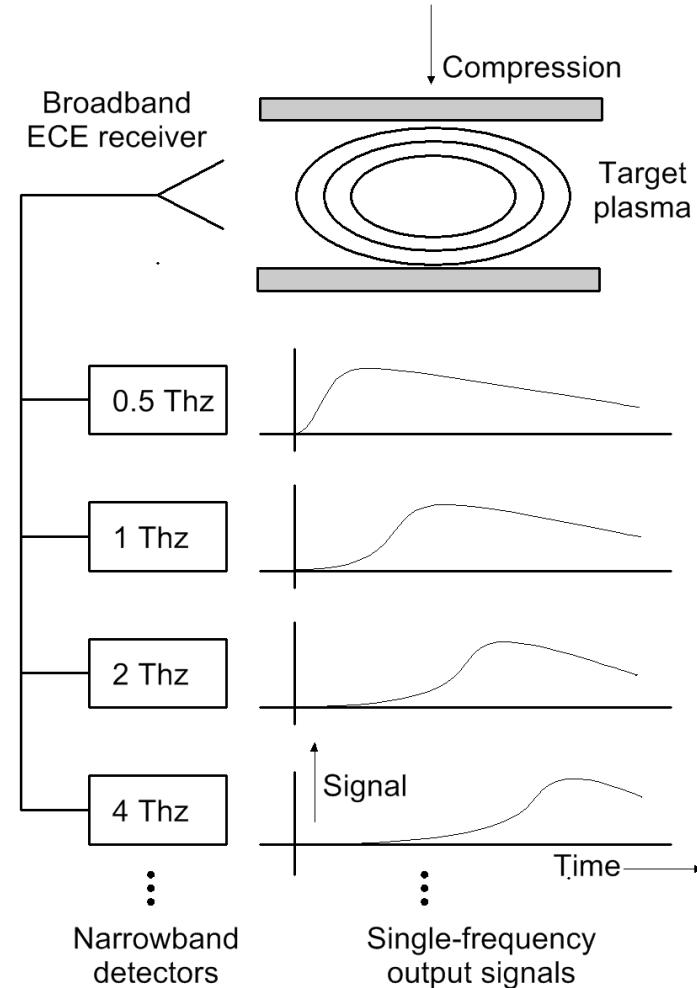
- $n_c \sim 7 \times 10^{21} \text{ cm}^{-3}$ at $\lambda = 400 \text{ nm}$
- **405 nm laser module- multi mode-- low coherence** **150mW CW**
- **405 nm laser module—single mode (CL~2cm)** **30mW CW**
- **370 nm laser module ----multi mode low coherence** **15mw CW**
- **Narrow band-pass filter for plasma light discrimination**

Characteristic Frequencies in MIF Parameter Space

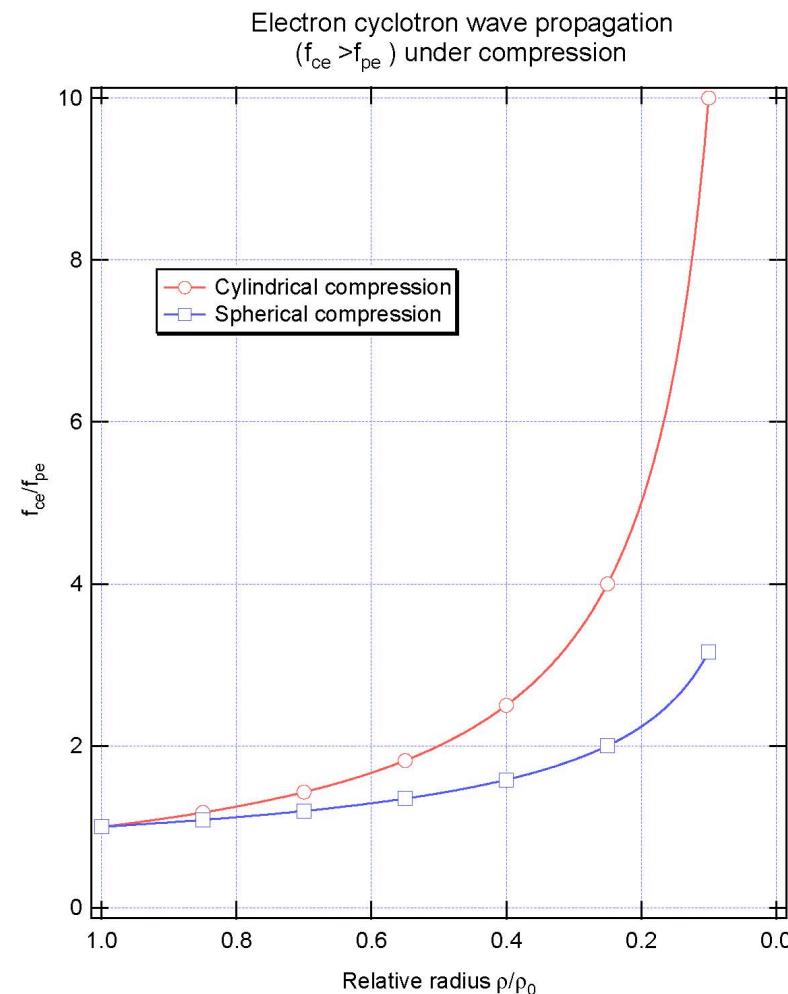


Terahertz ECE diagnostic (conceptual)

- Measures ECE in multiple frequency bands
- Potential diagnostic of magnetic field, electron temperature, electron density
- Heterodyne detection of B compression
- Time evolution of B dynamics

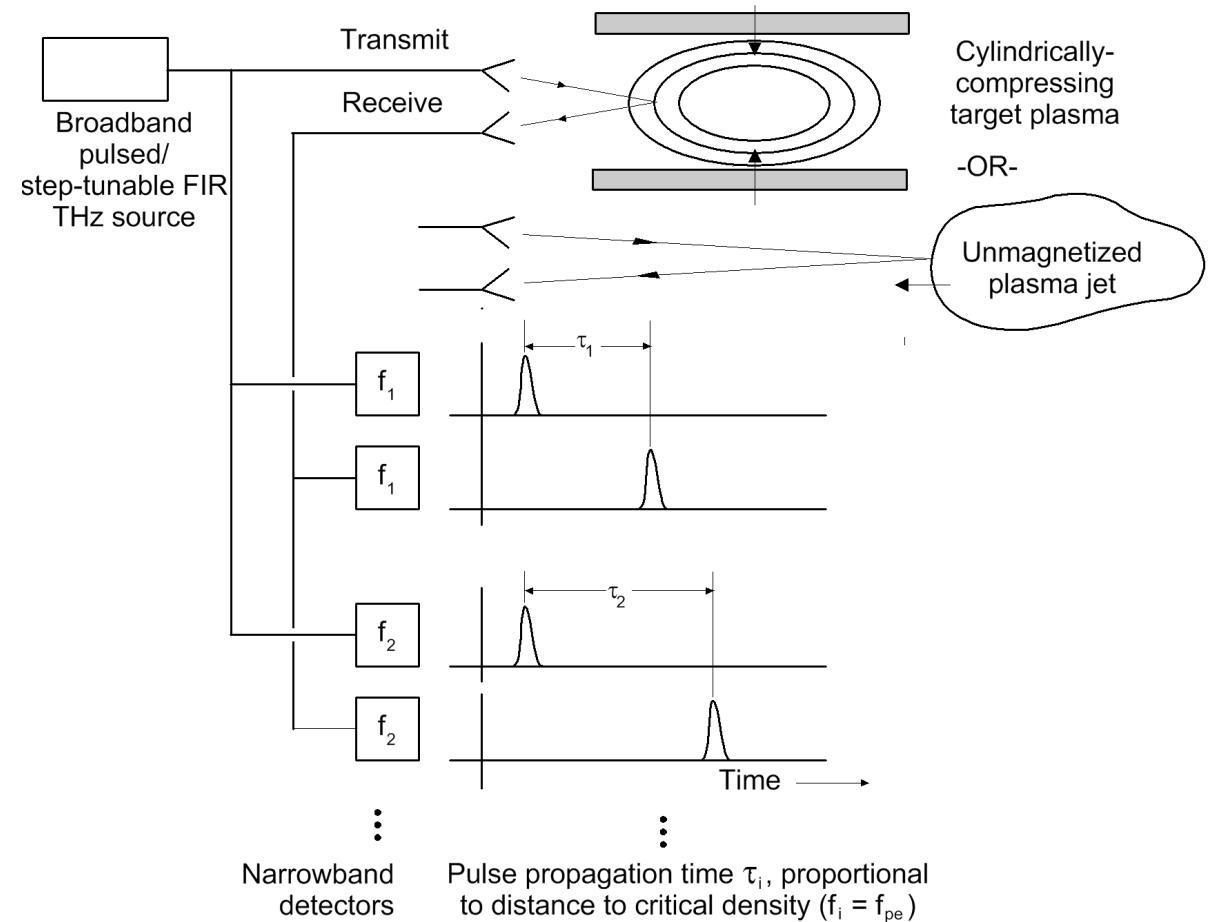


Propagation Condition for Cyclotron wave under Flux Conserving Compression



Terahertz reflection diagnostic (conceptual)

- **Measures location of plasma critical density ($f=f_{pe}$) by pulse time-of-flight**
- Can be used during plasma jet translation, target plasma formation, or target plasma compression
- Time evolution of target compression
- Time evolution of unmagnetized jet speed



Terahertz Technology Status

- **THz Quantum Cascade Laser (QCL)**
- **CO₂ driven step tunable FIR laser 1.5 to 6 THz**
- **Ultra-short- pulsed broad band sources (150 fsec pulsed)**
- **Schottky, SIS, HEB THz mixer/receivers**
- **Molecular dynamic studies**
- **Astrophysical studies (JPL)**

Path to fusion regime MIF diagnostics

- Testing diagnostic concepts on developing facilities
- Collaborative investigation on large MIF facilities
- Collaborative development with technology groups
- Graduate student training on special facilities
- Fusion charged particle measurements
- Zeeman spectroscopy/temperature interpretations
- Absorption spectroscopy